WHAT IS CLAIMED IS:

S06 A1

1. An image data analysis method, comprising:

fitting a profile from a selected family of profiles to a selected portion of image data representing an imaged object; and

computing a magnitude of an extensional feature of the imaged object based on the fit profile.

2. A method according to claim 1, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis; and

the extensional feature is a spatial extent of a structure of the imaged object at the axial position on the specified axis.

3. A method according to claim 2, wherein the imaged object comprises an organ of a living subject and the structure is a blood vessel of the organ.

4. A method according to claim 3, wherein the living subject is a human patient and the blood vessel is an artery.

5. A method according to claim 1, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis;

the selected portion of the image data represents a structure comprising a wall portion defining an interior region within the structure; and

the extensional feature is an area of a cross section of the interior region at the axial position on the specified axis.

6. A method according to claim 1, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis;

the selected portion of the image data represents a cross section of a structure of the imaged object; and

the extensional feature is an area of a region defined by the cross section of the structure.

7. A method according to claim 1, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis; and

the selected family of profiles is a family of functions of two independent variables.

8. A method according to claim 7, wherein the selected family of profiles is a family of two-dimensional Gaussian profiles.

9. A method according to claim 1, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis;

further image data represent one or more additional cross sections of the imaged object each at a successive additional position on the specified axis; and

the method further comprises computing magnitudes of the extensional feature of the imaged object at the one or more successive additional positions based on the further image data.

10. A method according to claim 9, further comprising:

fitting a further profile from a selected family of one-dimensional profiles to the computed magnitudes at the one or more successive additional positions; and

quantifying a spatial characteristic of a structure within the imaged object based on the further profile.

11. A method according to claim 10, wherein:

the further profile is a best fit profile having values approximating the computed magnitudes of the extensional feature at respective positions on the specified axis; and

quantifying the spatial characteristic comprises computing a maximum of differences between values of the best fit profile and corresponding values of a reference function specifying nominal magnitude values for the extensional feature.

12. A method according to claim 9, wherein the imaged object comprises an organ of a human subject and the extensional feature is a cross sectional area of a lumen of a vessel of the organ, the method further comprising:

fitting a further profile from a selected family of one-dimensional profiles to the computed magnitudes at the one or more successive additional positions; and

quantifying stenosis of the vessel based on the further profile.

13. A method according to claim 9, wherein the specified axis is a longitudinal axis of a structure within the imaged object.

14. A method for quantifying stenosis of a vessel from volumetric image data representing a three-dimensional portion of the vessel, the method comprising:

obtaining a plurality of successive image data sets based on the volumetric image data, each image data set representing a transverse cross section of the vessel with respect to a central axis thereof at a corresponding successive axial position;

selecting for each image data set a corresponding profile from a selected family of two-dimensional Gaussian profiles by fitting the corresponding profile to pixel data comprised in the image data set and representing a lumen of the vessel;

determining area values for the lumen at the corresponding axial positions from the selected profiles;

selecting a further profile from a selected family of one-dimensional profiles by fitting the further profile to the area values along the central axis; and

quantifying stenosis of the vessel based on the further profile.

15. A method according to claim 14, wherein obtaining the image data sets comprises reformatting at least a portion of the volumetric image data to generate each image data set on a corresponding grid transverse to the central axis of the vessel.

16. A method according to claim 15, wherein the reformatting operation comprises generating each image data set by interpolating between image data of selected portions of the volumetric image data.

17. A method according to claim 15, further comprising determining from the volumetric image data a space curve representing the central axis of the vessel.

18. A method according to claim 17, wherein the volumetric image data comprises a plurality of slice image data sets specifying successive slice images of the imaged object, and determining the space curve comprises:

identifying in each slice image data set a data portion corresponding to a lumen region of the vessel;

determining for each slice image data set a center position of the corresponding lumen region by a procedure comprising performing a moment calculation for the corresponding data portion; and

determining the space curve by performing a curve fitting calculation for the determined center positions.

Sub A1

19. An image data analyzing apparatus, comprising:

storage to store image data representing an imaged object; and

a processor to fit a profile from a selected family of profiles to a selected portion of the image data and to compute a magnitude of an extensional feature of the imaged object based on the fit profile.

20. An apparatus according to claim 19, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis; and

the extensional feature corresponds to a cross section of a structure in the imaged object at the axial position on the specified axis.

21. An apparatus according to claim 20, wherein the imaged object comprises an organ a living subject and the structure is a blood vessel of the organ.

22. An apparatus according to claim 21, wherein the living subject is a human patient and the blood vessel is an artery.

23. An apparatus according to claim 19, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis;

the selected portion of the image data represents a structure comprising a wall portion defining an interior region within the structure; and

the extensional feature is an area of a cross section of the interior region at the axial position on the specified axis.

24. An apparatus according to claim 19, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis;

the selected portion of the image data represents a cross section of a structure within the imaged object; and

the extensional feature is an area of a region defined by the cross section of the structure.

25. An apparatus according to claim 19, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis; and

the selected family of profiles is a family of functions of two independent variables.

26. An apparatus according to claim 25, wherein the selected family of profiles is a family of two-dimensional Gaussian profiles.

27. An apparatus according to claim 20, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis;

said storage stores further image data representing one or more additional cross sections of the imaged object each at a successive additional position on the specified axis; and

said processor computes magnitudes of the extensional feature of the imaged object at the one or more successive additional positions based on the further image data.

28. An apparatus according to claim 27, wherein:

said processor fits a further profile from a selected family of one-dimensional profiles to the computed magnitudes at the one or more successive additional positions; and

said processor quantifies a spatial characteristic of a structure within the imaged object based on the further profile.

29. An apparatus according to claim 28, wherein:

the further profile is a best fit profile having values approximating the computed magnitudes of the extensional feature at respective positions on the specified axis; and

said processor quantifies the spatial characteristic by computing a maximum of differences between values of the best fit profile and corresponding values of a reference function specifying nominal magnitude values for the extensional feature.

30. An apparatus according to claim 27, wherein:

the imaged object comprises an organ of a human subject and the extensional feature is a cross sectional area of a lumen of a vessel of the organ;

said processor fits a further profile from a selected family of one-dimensional profiles to the computed magnitudes the one or more successive additional positions; and

said processor quantifies stenosis of the artery based on the further profile.

31. An apparatus according to claim 30, wherein to quantify stenosis of the vessel said processor executes a computational procedure for estimating a reduction in cross-sectional area of the vessel relative to a reference cross-sectional area.

32. An apparatus according to claim 31, wherein:

said processor computes the reference cross-sectional area based on a reference function; and

the procedure for quantifying stenosis comprises comparing a value of the further profile and a corresponding value of the reference function.

33. An analysis system for quantifying stenosis of a vessel from volumetric image data generated by an imaging system and representing a three-dimensional portion of the vessel, said analysis system comprising:

a storage system to store some or all of the volumetric image data; and

a computer system comprising memory and a processor and programmed to execute procedures for

obtaining a plurality of successive image data sets based on the image data, each image data set representing a transverse cross section of the vessel with respect to a central axis thereof at a corresponding successive axial position,

selecting for each image data set a corresponding profile from a selected family of two-dimensional Gaussian profiles by fitting the

corresponding profile to pixel data comprised in the image data set and representing a lumen of the vessel,

determining area values for the lumen at the corresponding axial positions from the selected profiles,

selecting a further profile from a selected family of one-dimensional profiles by fitting the further profile to the area values along the central axis, and

quantifying stenosis of the vessel based on the further profile.

34. A system according to claim 33, wherein:

the volumetric image data have been generated by a procedure of tomographic image reconstruction from tomographic projection data corresponding to a rectilinear grid; and

said computer system obtains the plurality of successive image data sets by reformatting the volumetric image data to specify a plurality of tomographic slice images orthogonal to a central axis of the vessel.

35. A system according to claim 34, wherein said computer system generates each successive image data set by interpolating between selected portions of the volumetric image data.

36. A system according to claim 34, wherein said computer system selects a one-dimensional profile representing the central axis of the vessel based on the volumetric image data.

37. A system according to claim 36, wherein the volumetric image data comprises a plurality of slice image data sets specifying successive slice images of the imaged object, and said computer system selects the one-dimensional profile by a procedure comprising:

identifying in each slice image data set a data portion corresponding to a lumen region of the vessel;

determining for each slice image data set a center position of the corresponding lumen region by a procedure comprising performing a moment calculation for the corresponding data portion; and

determining the one-dimensional profile by performing a curve fitting calculation for the determined center positions.

38. A system according to claim 33, wherein said imaging system is an x-ray tomographic imaging system.

39. A system according to claim 33, wherein said imaging system is a magnetic resonance imaging system.

40. A system according to claim 33, wherein said imaging system is a multi-axis profiling x-ray imaging system.

Sub A1 41. A computer readable medium encoded with a program for image data analysis, said program comprising instructions for:

fitting a profile from a selected family of profiles to a selected portion of image data representing an imaged object; and

computing a magnitude of an extensional feature of the imaged object based on the fit profile.

42. A computer readable medium according to claim 41, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis; and

the extensional feature is a spatial extent of a structure of the imaged object at the axial position on the specified axis.

43. A computer readable medium according to claim 42, wherein the imaged object comprises an organ of a living subject and the structure is a blood vessel of the organ.

44. A computer readable medium according to claim 41, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis;

the selected portion of the image data represents a structure comprising a wall portion defining an interior region within the structure; and

the extensional feature is an area of a cross section of the interior region object at the corresponding axial position on the specified axis.

45. A computer readable medium according to claim 41, wherein:

the image data represent a cross section of the imaged object at a corresponding axial position on a specified axis; and

the selected family of profiles is a family of functions of two independent variables.

46. A structural assessment imaging method, comprising:

calculating quantitative information representing a structural feature of a volumetric structure in an imaged object, based on volumetric image data representing the imaged object;

generating sectional image data specifying a cross sectional image of the volumetric structure in a plane selected based on the quantitative information;

fitting a profile from a selected family of profiles to at least a portion of the sectional image data; and

computing a magnitude of an extensional feature of the volumetric structure based on the fit profile.

47. A method according to claim 46, wherein the generation of the sectional image data is further based on the volumetric image data.

48. A method according to claim 46, wherein the object is an organ of a human patient.

49. A method according to claim 48, wherein the volumetric structure is a vessel comprised in or adjoining the organ.

50. A method according to claim 46, wherein the volumetric structure is a vermiform structure.

51. A method according to claim 46, wherein:

the structural feature is a curvilinear longitudinal axis of the volumetric structure; and

the quantitative information comprises parametric values defining a parametric curve representing the curvilinear longitudinal axis.

52. A method according to claim 51, wherein the plane is selected to be orthogonal to a line tangent to the curvilinear longitudinal axis at a corresponding point at which the curvilinear longitudinal axis intersects the selected plane.

53. A method according to claim 46, further comprising generating additional sectional image data specifying an additional cross sectional image of the volumetric structure in an additional plane selected based on the quantitative information.

54. A method according to claim 46, wherein:

the volumetric structure is a tubular structure extending longitudinally along a curvilinear axis;

the extensional feature is a geometrical measure of the volumetric structure at a corresponding position relative to the curvilinear axis.

55. A method according to claim 46, further comprising:

generating plural sets of additional sectional image data each specifying an additional cross sectional image of the volumetric structure in an additional plane defined at a corresponding additional position and selected based on the quantitative information; and

computing magnitudes of the extensional feature of the volumetric structure at the plural additional positions based on the plural sets of additional sectional image data.

56. A method according to claim 55, further comprising:

fitting a further profile from a selected family of one-dimensional profiles to the computed magnitudes at the respective positions of the selected plane and the additional planes; and

quantifying a spatial characteristic of the volumetric structure based on the further profile.

57. An apparatus for structural assessment imaging, comprising:

at least one storage to store volumetric image data representing an imaged object; and

at least one processor to generate sectional image data specifying a cross sectional image of a volumetric structure of the imaged object, in a plane selected based on quantitative information representing a structural feature of the volumetric structure, and to compute a magnitude of an extensional feature of the structural feature based on a profile fit from a selected family of profiles to at least a portion of the sectional image data.

58. An apparatus according to claim 57, wherein said at least one processor generates the sectional image data based further on the volumetric image data.

59. An apparatus according to claim 57, wherein the object is an organ of a human patient.

60. An apparatus according to 59, wherein the volumetric structure is a vessel comprised in or adjoining the organ.

61. An apparatus according to 57, wherein the volumetric structure is a vermiform structure.

62. An apparatus according to claim 57, wherein:

the structural feature is a curvilinear longitudinal axis of the volumetric structure; and

said at least one processor generates the quantitative information to comprise parametric values defining a parametric curve representing the curvilinear longitudinal axis.

63. An apparatus according to claim 62, wherein the plane is selected to be orthogonal to a line tangent to the curvilinear longitudinal axis at a corresponding point at which the curvilinear longitudinal axis intersects the selected plane.

64. An apparatus according to claim 57, wherein said at least one processor further generates additional sectional image data specifying an additional cross sectional image of the volumetric structure in an additional plane selected based on the quantitative information.

65. An apparatus according to claim 57, wherein:

the volumetric structure is a tubular structure extending longitudinally along a curvilinear axis;

the extensional feature is a geometrical measure of the volumetric structure at a corresponding position relative to the curvilinear axis.

66. An apparatus according to claim 57, wherein said at least one processor generates plural sets of additional sectional image data, each specifying an additional cross sectional image of the volumetric structure in an additional plane defined at a corresponding additional position and selected based on the quantitative information, and computes magnitudes of the extensional feature of the volumetric structure at the plural additional positions based on the plural sets of additional sectional image data.

67. An apparatus according to claim 66, wherein said at least one processor further fits a further profile from a selected family of one-dimensional profiles to the computed magnitudes at the respective positions of the selected plane and the additional planes, and quantifies a spatial characteristic of the volumetric structure based on the further profile.

68. A computer readable medium encoded with a program for structural assessment imaging, said program comprising instructions for:

calculating quantitative information representing a structural feature of a volumetric structure in an imaged object, based on volumetric image data representing the imaged object;

generating sectional image data specifying a cross sectional image of the volumetric structure in a plane selected based on the quantitative information;

fitting a profile from a selected family of profiles to at least a portion of the sectional image data; and

computing a magnitude of an extensional feature of the volumetric structure based on the fit profile.

69. A computer readable medium according to claim 68, wherein the instructions of said program comprise instructions for generating the sectional image data based further on the volumetric image data.

70. A computer readable medium according to claim 68, wherein the object is an organ of a human patient.

71. A computer readable medium according to claim 70, wherein the volumetric structure is a vessel comprised in or adjoining the organ.

72. A computer readable medium according to claim 68, wherein the volumetric structure is a vermiform structure.

73. A computer readable medium according to claim 68, wherein:

the volumetric structure is a tubular structure extending longitudinally along a curvilinear axis; and

the extensional feature is a geometrical measure of the volumetric structure at a corresponding point on the curvilinear axis.

74. A computer readable medium according to claim 73, wherein said program comprises instructions for selecting the plane to intersect the curvilinear axis at the corresponding point and to be orthogonal to a line tangent to the curvilinear axis at the corresponding point.

75. A computer readable medium according to claim 68, wherein said program further comprises instructions for generating additional sectional image data specifying an additional cross sectional image of the volumetric structure in an additional plane selected based on the quantitative information.

76. A computer readable medium according to claim 68, wherein:

the volumetric structure is a tubular structure extending longitudinally along a curvilinear axis;

the extensional feature is a geometrical measure of the volumetric structure at a corresponding position relative to the curvilinear axis.

77. A computer readable medium according to claim 68, wherein said program further comprises instructions for:

generating plural sets of additional sectional image data each specifying an additional cross sectional image of the volumetric structure in an additional plane selected based on the quantitative information at a corresponding position relative to a specified axis through the volumetric structure and transverse to the selected plane; and

computing magnitudes of the extensional feature of the volumetric structure at the plural additional positions based on the further sectional image data sets.

78. A computer readable medium according to claim 77, wherein said program further comprises instructions for:

fitting a further profile from a selected family of one-dimensional profiles to the computed magnitudes at the respective positions of the selected plane and the additional planes; and

quantifying a spatial characteristic of the volumetric structure based on the further profile.

79. A method for quantifying stenosis of a vessel from volumetric image data representing a three-dimensional portion of the vessel, the method comprising:

obtaining a plurality of successive slice image data sets based on the volumetric image data, each slice image data set representing a transverse cross section of the vessel with respect to a central axis thereof at a corresponding successive axial position;

identifying in each slice image data set a data portion comprising pixel data corresponding to a lumen region of the vessel;

generating for each slice image data set a sum of brightness values of the corresponding pixel data;

determining area estimates for cross sections of the lumen region at the corresponding axial positions based on the sums; and

quantifying stenosis of the vessel based on the determined area estimates.

80. A method according to claim 79, wherein obtaining the slice image data sets comprises reformatting at least a portion of the volumetric image data to generate each slice image data set on a corresponding grid transverse to the central axis of the vessel.

81. A method according to claim 80, wherein reformatting at least a portion of the volumetric image data comprises generating each slice image data set by interpolating between image data of selected portions of the volumetric image data.

82. A method according to claim 79, further comprising determining from the volumetric image data a space curve representing the central axis of the vessel.

83. A method according to claim 82, wherein the volumetric image data comprises a plurality of initial slice image data sets specifying successive slice images of the imaged object, and determining the space curve comprises:

identifying in each initial slice image data set a data portion corresponding to the lumen region of the vessel;

determining for each initial slice image data set a center position of the corresponding lumen region by a procedure comprising performing a moment calculation for the corresponding data portion; and

determining the space curve by performing a curve fitting calculation for the determined center positions.

84. A method according to claim 83, wherein the curve fitting calculation comprises a least squares calculation to determine the space curve as a best-fit curve for the determined center positions.

85. A method according to claim 79, wherein quantifying stenosis of the vessel comprises:

selecting a profile from a selected family of one-dimensional profiles by fitting the profile to the determined area estimates along the central axis; and

determining a stenosis estimate for the vessel based on the selected profile.

86. A method according to claim 85, wherein determining the stenosis estimate comprises:

determining a reference profile from the selected family of one-dimensional profiles, the reference profile representing lumen cross sectional areas expected for a vessel without stenosis; and

computing the stenosis estimate based on respective values of the selected profile and the reference profile at a specified position along the central axis.

87. A method according to claim 86, further comprising:

determining a difference profile by subtracting the selected profile from the reference profile; and

selecting the specified position as a position on the central axis at which the difference profile assumes a maximum value.

88. An analysis system for quantifying stenosis of a vessel from volumetric image data generated by an imaging system and representing a three-dimensional portion of the vessel, said analysis system comprising:

a storage system to store some or all of the volumetric image data; and

a computer comprising memory and a processor and programmed to execute procedures for

obtaining a plurality of successive slice image data sets based on the volumetric image data, each slice image data set representing a transverse cross section of the vessel with respect to a central axis thereof at a corresponding successive axial position;

identifying in each slice image data set a data portion comprising pixel data corresponding to a lumen region of the vessel;

generating for each slice image data set a sum of brightness values of the corresponding pixel data; and

determining area estimates for cross sections of the lumen region at the corresponding axial positions based on the sums; and

quantifying stenosis of the vessel based on the determined area estimates.

89. A system according to claim 88, wherein said computer obtains the slice image data sets by executing a procedure comprising reformatting at least a portion of the volumetric image data to generate each image data set on a corresponding grid transverse to the central axis of the vessel.

90. A system according to claim 89, wherein said computer reformats the at least a portion of the volumetric image data by executing a procedure comprising generating each image data set by interpolating between image data of selected portions of the volumetric image data.

91. A system according to claim 89, wherein said computer further executes a procedure for determining from the volumetric image data a space curve representing the central axis of the vessel.

92. A system according to claim 91, wherein the volumetric image data comprises a plurality of initial slice image data sets specifying successive slice images of the imaged object, and the procedure for determining the space curve comprises:

identifying in each initial slice image data set a data portion corresponding to the lumen region of the vessel;

determining for each initial slice image data set a center position of the corresponding lumen region by a procedure comprising performing a moment calculation for the corresponding data portion; and

determining the space curve by performing a curve fitting calculation for the determined center positions.

93. A system according to claim 88, wherein quantifying stenosis of the vessel comprises:

selecting a profile from a selected family of one-dimensional profiles by fitting the profile to the determined area estimates along the central axis; and

determining a stenosis estimate for the vessel based on the selected profile.

94. A system according to claim 93, wherein determining the stenosis estimate comprises:

determining a reference profile from the selected family of one-dimensional profiles, the reference profile representing lumen cross sectional areas expected for a vessel without stenosis; and

computing the stenosis estimate based on respective values of the selected profile and the reference profile at a specified position along the central axis.

95. A system according to claim 94, wherein said computer further executes procedures for:

determining a difference profile by subtracting the selected profile from the reference profile; and

selecting the specified position as a position on the central axis at which the difference profile assumes a maximum value.

96. A computer readable medium encoded with a program for quantifying stenosis of a vessel from volumetric image data representing a three-dimensional portion of the vessel, said program comprising instructions for:

obtaining a plurality of successive slice image data sets based on the volumetric image data, each slice image data set representing a transverse cross section of the vessel with respect to a central axis thereof at a corresponding successive axial position;

identifying in each slice image data set a data portion comprising pixel data corresponding to a lumen region of the vessel;

generating for each slice image data set a sum of brightness values of the corresponding pixel data; and

determining area estimates for cross sections of the lumen region at the corresponding axial positions based on the sums; and

quantifying stenosis of the vessel based on the determined area estimates.

97. A computer readable medium according to claim 96, wherein the instructions for obtaining the slice image data sets comprise instructions for reformatting at least a portion of the volumetric image data to generate each slice image data set on a corresponding grid transverse to the central axis of the vessel.

98. A computer readable medium according to claim 97, wherein the instructions for reformatting the at least a portion of the volumetric image data comprise instructions for generating each slice image data set by interpolating between image data of selected portions of the volumetric image data.

99. A computer readable medium according to claim 97, wherein said program further comprises instructions for determining from the volumetric image data a space curve representing the central axis of the vessel.

100. A computer readable medium according to claim 99, wherein:

the volumetric image data comprises a plurality of initial slice image data sets specifying successive slice images of the imaged object; and

the instructions for determining the space curve comprise instructions for

identifying in each initial slice image data set a data portion corresponding to the lumen region of the vessel,

determining for each initial slice image data set a center position of the corresponding lumen region by a procedure comprising performing a moment calculation for the corresponding data portion, and

determining the space curve by performing a curve fitting calculation for the determined center positions.

101. A computer readable medium according to claim 96, wherein the instructions for quantifying stenosis of the vessel comprise instructions for:

selecting a profile from a selected family of one-dimensional profiles by fitting the profile to the determined area estimates along the central axis; and

determining a stenosis estimate for the vessel based on the selected profile.

102. A computer readable medium according to claim 101, wherein the instructions for determining the stenosis estimate comprise instructions for:

determining a reference profile from the selected family of one-dimensional profiles, the reference profile representing lumen cross sectional areas expected for a vessel without stenosis; and

computing the stenosis estimate based on respective values of the selected profile and the reference profile at a specified position along the central axis.

103. A computer readable medium according to claim 102, wherein said program further comprises instructions for:

determining a difference profile by subtracting the selected profile from the reference profile; and

selecting the specified position as a position on the central axis at which the difference profile assumes a maximum value.